

What is claimed is:

1                   1.       A charged particle beam apparatus comprising:  
2                   a stage for setting a sample;  
3                   a charged particle optical system for converging a charged particle beam  
4 emitted by a charged particle source;  
5                   a scanning means for irradiating said charged particle beam converged by  
6 said charged particle optical system to said sample in order to scan said sample;  
7                   a focal point control system for controlling a focal point of said charged  
8 particle beam converged by said charged particle optical system;  
9                   an astigmatism adjustment means for adjusting astigmatism of said  
10 charged particle beam converged by said charged particle optical system;  
11                   a particle image detection means for obtaining a 2 dimensional particle  
12 image by detection of a particle image generated by said sample scanned by radiation of  
13 said charged particle beam converged by said charged particle optical system;  
14                   an image processing means for computing a focal offset and said  
15 astigmatism of said converged charged particle beam on the basis of said 2 dimensional  
16 particle image obtained by said particle image detection means; and  
17                   a control system for adjusting and controlling said astigmatism of said  
18 converged charged particle beam by feeding back an astigmatism correction quantity  
19 based on said astigmatism computed by said image processing means to said astigmatism  
20 adjustment.

1                   2.       A charged particle beam apparatus according to claim 1, wherein  
2 said control system for adjusting and controlling further provides adjusting and  
3 controlling of said focal point of said converged charged particle beam by feeding back a  
4 focal point correction quantity based on said focal offset computed by said image  
5 processing means to said focal point control system.

1                   3.       A charged particle beam apparatus according to claim 1, wherein  
2 said charged particle beam apparatus creates a pattern, said pattern including edge  
3 components in at least 3 directions on said sample.

1                   4.       A charged particle beam apparatus according to claim 3, wherein  
2 said charged particle beam apparatus creates said pattern including edge components in at

3 least 3 directions, said pattern having at least 3 areas, each of said areas for creating a sub  
4 pattern having one of said edge components in one of said directions on said sample.

1 5. A charged particle beam apparatus according to claim 1, wherein said  
2 astigmatism in said image processing means is any selected from a magnitude and a  
3 direction of said astigmatism and a vector of said astigmatism.

1 6. A charged particle beam apparatus according to claim 1, wherein  
2 said particle image detection means detects a particle image generated from said sample  
3 serving as an object substrate as a result of radiation of said converged charged particle  
4 beam with at least said astigmatism adjusted and controlled by said control system to said  
5 object substrate in a scanning operation carried out by using said scanning means; and  
6 a defect inspection image processing means is provided for inspecting said  
7 object substrate for a defect existing on said object substrate on the basis of said detected  
8 particle image.

1 7. A charged particle beam apparatus according to claim 6, wherein  
2 control of said focal point control system is based on a height on said object substrate  
3 optically detected by a height detection sensor further provided for optically detecting a  
4 height on said object substrate.

1 8. A charged particle beam apparatus according to claim 1, wherein  
2 said particle image detection means detects a particle image generated from said sample  
3 serving as an object substrate as a result of radiation of said converged charged particle  
4 beam with at least said astigmatism adjusted and controlled by said control system to said  
5 object substrate in a scanning operation carried out by using said scanning means; and  
6 a measurement image processing means is provided for measuring  
7 dimensions of a pattern existing on said object substrate on the basis of said detected  
8 particle image.

1 9. A charged particle beam apparatus according to claim 8, wherein  
2 control of said focal point control system is based on a height on said object substrate  
3 optically detected by a height detection sensor further provided for optically detecting a  
4 height on said object substrate.

1 10. A charged particle beam apparatus comprising:

2 a stage for setting a sample;  
3 a charged particle optical system for converging a charged particle beam  
4 emitted by a charged particle source;  
5 a scanning means for radiating said charged particle beam converged by  
6 said charged particle optical system to said sample in order to scan said sample;  
7 a focal point control system for controlling a focal point of said charged  
8 particle beam converged by said charged particle optical system;  
9 an astigmatism adjustment means for adjusting astigmatism of said  
10 charged particle beam converged by said charged particle optical system;  
11 a particle image detection means for obtaining a 2 dimensional particle  
12 image having a plurality of focal point positions by detection of a particle image with a  
13 plurality of focal point positions generated by said sample scanned by radiation of said  
14 charged particle beam converged by said charged particle optical system;  
15 an image processing means for computing said astigmatism of said  
16 converged charged particle beam on the basis of said 2 dimensional particle image with a  
17 plurality of focal point positions obtained by said particle image detection means; and  
18 a control system for adjusting and controlling said astigmatism of said  
19 converged charged particle beam by feeding back an astigmatism correction quantity  
20 based on said astigmatism computed by said image processing means to said astigmatism  
21 adjustment means.

1 11. A charged particle beam apparatus according to claim 10, wherein  
2 said control system for adjusting and controlling further provides adjusting and  
3 controlling of said focal point of said converged charged particle beam by feeding back a  
4 focal point correction quantity based on said focal offset computed by said image  
5 processing means to said focal point control system.

1 12. A charged particle beam apparatus according to claim 10, wherein  
2 said image processing means computes said astigmatism of said converged charged  
3 particle beam from a relation among in focus positions at directional sharpness  
4 magnitudes for at least 3 directions by finding said directional sharpness magnitudes for  
5 at least said 3 directions for a plurality of focal point positions from said 2 dimensional  
6 particle image with a plurality of focal point positions obtained by said particle image

7 detection means and then finding said in focus positions at said found directional  
8 sharpness magnitudes for at least said 3 directions.

1 13. A charged particle beam apparatus according to claim 12, wherein  
2 said control system for adjusting and controlling further provides adjusting and  
3 controlling of said focal point of said converged charged particle beam by feeding back a  
4 focal point correction quantity based on said focal offset computed by said image  
5 processing means to said focal point control system.

1 14. A charged particle beam apparatus according to claim 12, wherein  
2 said image processing means has a configuration wherein directional sharpness  
3 magnitudes in at least 3 directions are found by carrying out directional differentiation  
4 processing in at least 3 directions.

1 15. A charged particle beam apparatus according to claim 12, wherein  
2 said image processing means has a configuration wherein directional sharpness  
3 magnitudes in at least 3 directions are found by computing amplitudes of a particle image  
4 in at least 3 directions.

1 16. A charged particle beam apparatus according to claim 12, wherein  
2 said image processing means has a configuration wherein directional sharpness  
3 magnitudes in at least 3 directions are found by texture strengths for pattern components  
4 in at least 3 directions from a Fourier spectrum of a particle image.

1 17. A charged particle beam apparatus according to claim 10, wherein  
2 said particle image detection means has a configuration wherein a particle image having a  
3 plurality of different focal point positions is detected from said sample by controlling said  
4 focal point control means.

1 18. A charged particle beam apparatus according to claim 10, said  
2 charged particle beam apparatus characterized in that said particle image detection means  
3 has a configuration wherein a particle image having a plurality of different focal point  
4 positions is detected from a plurality of different areas on said sample.

1 19. A charged particle beam apparatus according to claim 18, wherein  
2 said sample is inclined or has a staircase like surface.

1                   20.     A charged particle beam apparatus according to claim 18, wherein  
2     said converged charged particle beam is radiated to said sample and scanned over said  
3     sample by changing said focal point position at a high speed.

1                   21.     A charged particle beam apparatus according claim 12, wherein  
2     said image processing means determines said in focus position for each of said directional  
3     sharpness magnitudes by:

4                   finding a maximum value for each of said directional sharpness  
5     magnitudes;

6                   applying a function having a peak such as a quadratic function or a  
7     Gaussian function by using values preceding and succeeding said maximum value;

8                   finding a true peak value by interpolation; and

9                   using the position of said true peak value as said in focus position.

1                  22.     A charged particle beam apparatus according to claim 21, wherein,  
2     if a plurality of maximum values exist for each of said directional sharpness magnitudes,  
3     a weighted average of peak positions of said maximum values with weights thereof set in  
4     accordance with heights at said peak positions is found as an in focus position.

1                  23.     A charged particle beam apparatus according to claim 12, wherein  
2     said image processing means determines an in focus position for each of directional  
3     sharpness magnitudes as a center of gravity of an area enclosed by a segment of a curve  
4     and a horizontal line representing a threshold value where said curve represents variations  
5     of each of said directional sharpness magnitudes with respect to said in focus position  
6     whereas said segment represents said variations exceeding said threshold value.

1                  24.     A charged particle beam apparatus according claim 12, wherein  
2     said image processing means determines said in focus position for each of directional  
3     sharpness magnitudes by:

4                   computing a degree of matching between a curve representing variations  
5     of an evaluation value with respect to each of said directional sharpness magnitudes and  
6     any one of curves of image inversion which are each symmetrical with respect to an axis  
7     of symmetry on the right and left sides of said axis of symmetry;

8                   determining a specific one of said curves of image inversion with a highest  
9     degree of matching; and

10 using the position of an axis of symmetry of said specific curve of image  
11 inversion as said in focus position.

1 25. A charged particle beam apparatus according to claim 12, said  
2 charged particle beam apparatus further comprising:  
3 a standard sample is provided for calibration purposes at a location  
4 adjacent to an object substrate;  
5 at least astigmatism or a focal point is corrected on said standard sample  
6 prior to an observation, an inspection or a measurement of said object substrate or  
7 periodically; wherein said observation, said inspection or said measurement of said object  
8 substrate is carried out in a state of corrected astigmatism or a corrected focal point.

1 26. An automatic astigmatism adjustment method comprising:  
2 converging a charged particle beam emitted by a charged particle source;  
3 radiating said converged charged particle beam to a sample with a pattern  
4 created thereon;  
5 obtaining a 2 dimensional particle image by detection of particles  
6 generated from said sample by said radiating;  
7 computing a focal offset and astigmatism of said converged charged  
8 particle beam based on said 2 dimensional particle image; and  
9 adjusting and controlling said astigmatism of said converged charged  
10 particle beam based on a feed back of an astigmatism correction quantity computed based  
11 upon said astigmatism; and said focal point of said converged charged particle beam  
12 based on a feed back a focal point correction quantity computed based upon said focal  
13 offset.

1 27. An automatic astigmatism adjustment method comprising:  
2 converging a charged particle beam emitted by a charged particle source;  
3 radiating said converged charged particle beam to a sample with a pattern  
4 created thereon;  
5 changing a focal point of said converged charged particle beam;  
6 obtaining a plurality of 2 dimensional particle images having different  
7 focal points of said converged charged particle beam by detection of particles generated  
8 from said sample by said radiating;

9                    computing astigmatism of said converged charged particle beam based on  
10 said obtained plurality of 2 dimensional particle images; and  
11                    adjusting and controlling said astigmatism of said converged charged  
12 particle beam by feeding back an astigmatism correction quantity computed based upon  
13 said astigmatism.

1                    28.    An automatic astigmatism adjustment method comprising:  
2                    converging a charged particle beam emitted by a charged particle source;  
3                    radiating said converged charged particle beam to a sample with a pattern  
4 created thereon;  
5                    obtaining a plurality of 2 dimensional particle images having different  
6 focal points of said converged charged particle beam by detection of particles generated  
7 from said sample by said radiating;  
8                    computing a focal offset and astigmatism of said converged charged  
9 particle beam based on said obtained plurality of 2 dimensional particle images; and  
10                   adjusting and controlling said astigmatism of said converged charged  
11 particle beam by feeding back an astigmatism correction quantity computed based upon  
12 said astigmatism; and said focal point of said converged charged particle beam by feeding  
13 back a focal point correction quantity computed based on said focal offset.

1                    29.    An automatic astigmatism adjustment method comprising:  
2                    converging a charged particle beam emitted by a charged particle source;  
3                    radiating said converged charged particle beam to a sample with a pattern  
4 created thereon;  
5                    obtaining a plurality of 2 dimensional particle images having different  
6 focal points of said converged charged particle beam by detection of particles generated  
7 from said sample by said radiating;  
8                    computing directional sharpness magnitudes for at least 3 directions from  
9 said plurality of 2 dimensional particle images;  
10                   computing in focus positions using said computed directional sharpness  
11 magnitudes for at least said 3 directions;  
12                   computing astigmatism of said converged charged particle beam from a  
13 relation among said computed in focus positions at said computed directional sharpness  
14 magnitudes for at least said 3 directions; and

15 adjusting and controlling said astigmatism of said converged charged  
16 particle beam by feeding back an astigmatism correction quantity computed based on said  
17 astigmatism.

1 30. The automatic astigmatism adjustment method of claim 29, further  
2 comprising:

3 repeating said converging through said adjusting and controlling until said  
4 astigmatism correction quantity is sufficiently small.

1 31. An automatic astigmatism adjustment method comprising:  
2 converging a charged particle beam emitted by a charged particle source;  
3 radiating said converged charged particle beam to a sample with a pattern  
4 created thereon;

5 obtaining a plurality of 2 dimensional particle images having different  
6 focal points of said converged particle beam by detection of particles generated from said  
7 sample by said radiating;

8 computing directional sharpness magnitudes for at least 3 directions for a  
9 plurality of focal point positions from said plurality of 2 dimensional particle images;  
10 computing in focus positions using said computed directional sharpness  
11 magnitudes for at least said 3 directions;

12 computing astigmatism of said converged charged particle beam from a  
13 relation among said computed in focus positions at said computed directional sharpness  
14 magnitudes for at least said 3 directions; and

15 controlling said astigmatism of said converged charged particle beam by  
16 feeding back an astigmatism correction quantity computed based on said astigmatism;  
17 and said focal point of said converged charged particle beam by feeding back a focal  
18 point correction quantity computed based on said in focus positions.

1 32. An automatic astigmatism adjustment method according to claim  
2 31, wherein said computing in focus position using said computed directional sharpness  
3 magnitudes further comprises:

4 computing a maximum value for each of said directional sharpness  
5 magnitudes;



6           applying a function having a peak such as a quadratic function or a  
7   Gaussian function by using values preceding and succeeding said maximum value;  
8           computing a true peak value by interpolation; and  
9           using the position of said true peak value as said in focus position.

1           33.    An automatic astigmatism adjustment method according to claim  
2   32, wherein if a plurality of maximum values exist for each of said directional sharpness  
3   magnitudes, a weighted average of peak positions of said maximum values with weights  
4   thereof set in accordance with heights at said peak positions is computed as an in focus  
5   position.

1           34.    An automatic astigmatism adjustment method according to claim  
2   31, wherein said computing an in focus position using said computed directional  
3   sharpness magnitudes further comprises:  
4           computing a center of gravity of an area enclosed by a segment of a curve  
5   and a horizontal line representing a threshold value where said curve represents variations  
6   of each of said computed directional sharpness magnitudes with respect to said in focus  
7   position; and wherein said segment represents said variations exceeding said threshold  
8   value.

1           35.    An automatic astigmatism adjustment method according to claim  
2   31, wherein said computing an in focus position using said computed directional  
3   sharpness magnitudes further comprises:  
4           computing a degree of matching between a curve representing variations  
5   of an evaluation value with respect to each of said directional sharpness magnitudes and  
6   any one of curves of image inversion which are each symmetrical with respect to an axis  
7   of symmetry on the right and left sides of said axis of symmetry;  
8           determining a specific one of said curves of image inversion with a highest  
9   degree of matching; and  
10          using the position of an axis of symmetry of said specific curve of image  
11   inversion as said in focus position.